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The Effect of Foliar Application of Nano-chelate Super Plus ZFM on Fruit Set and some Quantitative and Qualitative Traits of Almond Commercial Cultivars

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Abstract

The nutritional problems in almond orchards have increased because of alkaline soils and insufficient nutrition. This study was done to evaluate the effect of nano-chelate super plus ZFM (Zinc, Iron and Manganese) spraying on quantitative and qualitative characteristics of almond commercial cultivars. This work was carried out in factorial experiment base on randomized complete block design with three replications. A factor involved different almond cultivars (Shokufeh, Mon-agha and Sahand) and B factor involved the time of nano-chelate super plus ZFM (2g/l) application with four time treatments T1: bud swelling phase, T2: two weeks after bloom end and T3: Application in two stages, bud swelling phase (T1) and two weeks after bloom (T2) and T4: control (spraying with water). Different traits, such as yield per shoot, initial and final fruit set; fruit abscission, length, width and fresh and dry weight of nut and concentration of microelements in leaves were measured. The results showed that the concentration of micro elements (Zn, Fe, Cu and Mn) in leaves increased significantly in all treatments especially when spraying in two stages compared to control. Also, the interaction of time of spraying and cultivar was significant in all measured traits except fruit abscission. The highest percentages of initial and final fruit set and yield per shoot were observed in Shokufeh cultivar and fertilizer spraying in two stages (T1 and T2), and the lowest percentage of initial and final fruit set was observed in control in all tested cultivars. The simple effect of spraying time on fruit abscission was significant in 1% level and also percentage of fruit abscission decreased about 25% compared to control in application in two times (T1 and T2).

Keywords: Bloom end phase, Nano-chelate, Nutritional problems, Spraying, Swelled bud phase**.**

Introduction

Almond *(Prunus dulcis*) tree belongs to the rosaceous family (Ghaderi *et al*., 2004) and with 146055 hectares of land under cultivation; it is one of the important horticultural products in Iran. Iran is one of the largest almond producers in the world (FAO, 2010). Geographical conditions of some regions of Iran are very suitable for almond growth but its low yield is a considerable problem in Iran compared to other countries. Insufficient nutrition and alkaline soil can be the reasons of this problem. India, Europe and China are the most important importers of world's almond, respectively and the USA is the first almond exporter to these countries, Iran provides only a small amount of almond consumption of European countries and India. Our country has many advantages in terms of location and cost of production and transport of this product to China against American product. The extent of the market and high price of this product in China is a golden opportunity for Iran's almond industry to provide a constant presence in this market and provide the necessities for prosperity of this industry within our

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country (Zareh, 2008).

Today, foliar spraying of nutrients in most of the fruit orchards in the world has become usual and its positive effects on shoot and fruit growth characteristics are evident (Hossenifard and Alipoor, 2009). Baybordi *et al*. (2005) showed that foliar spraying of Zinc and Boron on almond increased the fruit set. Ghaderi *et al*. (2004) also reported that almond yield increased after foliar spraying of Zinc and Boron microelements.

Since most of the soils of Kerman province are alkaline, absorption of micronutrients by plants is difficult. Therefore, as a result, the lack of these elements in plants can be an important factor in reducing the fruit set.

Iron is one of the essential elements for the growth of all plants and in the case of iron deficiency; chlorophyll is not produced sufficiently in leaf cells, resulting in chlorosis and yellow leaves (Baybordi, 2005). The amount of zinc in soil solutions is very small and when the pH of soil increases, the amount of available zinc for plants is reduced. This microelement has actuator catalytic or structural roles in many of the enzymatic systems of plants and also it is involved in construction and destruction of proteins in plants. On the other hand, zinc has the main role in acceleration of pollen germination and tube growth at the time of pollination and pollen germination and so it allows the fertilization and fruit set to increase (Baybordi, 2005). Manganese is essential microelement in the production of chlorophyll and also Nitrogen metabolism and aqueous reactions of photosynthesis are affected by manganese. It plays essential roles in reproductive activities, pollination, cell division in meristematic tissues, repair of vascular tissues and metabolism and transfer of carbohydrates (Movahedi dehnoy *et al*., 2009). In soils with sandy texture, manganese is washed by rainfall or irrigation and becomes unavailable for plants. Also at pHs above eight and in alkaline soils, boron absorption is greatly reduced due to the interaction between calcium and boron (Swietlike and faust, 1984).

Today, it is also known that plants can use amino acids as the nitrogen source (Molaei *et al*., 2013). Kamiab *et al*., (2015) reported that foliar spraying of amino acids increased the quantitative and qualitative characteristics of pistachio. Usually the number of fruit increases with nitrogen supply, if other factors are not limiting. Insufficient nitrogen supply limits the flowering and increases the tendency to alternate bearing. Fruit set increases with increasing nitrogen content in flower buds. Acceptance period of ovule for fertilization becomes short, when flower buds are weak. With repairing the weakness of flowering by increasing the nitrogen supply after crop harvest and before popcorn (balloon) stage, the ovule longevity can be increased (Kelin, 1984). One of the most important problems of almond cultivars is reduced fruit set after the bloom end that greatly reduces the yield. Thus, it seems that the application of the nano-chelate super plus ZFM which contains micro-elements with amino acids as nitrogen source and with ascorbic acid as a strong antioxidant would be very effective and would significantly increase the fruit set and yield. On the other hand, the nano-chelate super plus ZFM is a fertilizer that is produced by nanotechnology and has excellent properties such as higher absorption at lower concentrations. If application of this fertilizer is effective, it would be economically affordable. Given the importance of almond export and sufficient nutrition of almond trees, the effect of this fertilizer on quantity and quality of almond in this study was evaluated. The objective of this study was to investigate the effect of foliar application of ZFM super plus fertilizer on increasing the fruit set and yield in almond.

Materials and Methods

This experiment was performed in the spring of 2015 in almond orchards located in Sarqashk village of Rabor city in Kerman province. Geographical and climate characteristics of orchard and chemical analysis of its soil are shown in Tables 1, 2 and 3.

Table 1. Geographic and climatic characteristics of Saffron Research Farm of Shahed University

Longitude	Latitude	Altitude(m)	Maximum temperature (°C)	Minimum temperature(°C)	Climate	Rainfall(mm/year)
56° .45′	32° .54 ′	790	40	-3	Semi-arid	250

Table 2. Chemical analysis of almond orchard Soil in Sarqashk village

Texture soil	pH	Sodium absorption ratio(SAR)	Absorbable potassium (ppm)	Absorbable phosphor (ppm)	Total nitrogen N%	Saturation percentage (%)	Electrical conductivity (ds.m)	Depth (cm)
Sandy- clay	8	14.8	250	13.77	0.05	28	7.2	0-30

Table 3. Chemical analysis of some macro and micro elements of almond orchard Soil in Sarqashk village

Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	B (ppm)	S (ppm)	Mg (ppm)
6	2	0.6	5	1.1	14.8	16.3

The experiment was carried out in as a factorial base on randomized complete block design with three replications. A factor involved different almond cultivars (Shokufeh, Monagha and Sahand). It is essential to state that there were several cultivars of almond with different flowering time for pollination in this orchard. B factor involved time of application of the nano-chelate super plus ZFM in four treatments T1: bud swelling phase, T2: two weeks after full bloom and T3: Application in two stages, bud swelling phase (T1) and two weeks after full bloom (T2) and also T4: control (spraying with Distilled water). There were 12 treatments with 3 replications in this experiment and two trees in each plot (totally 72 trees) were compared.

This fertilizer is a powerful combination of micro elements, particularly iron (8%), zinc (6%) and manganese (4%). In addition, it contains other elements such as magnesium, copper, boron, molybdenum, calcium (2%), amino acids (hydroxyproline, aspartic acid, threonine, serine, proline, Glutamic acid, glycine, alanine, arginine, methionine, isoleucine, leucine, tyrosine, phenylalanine, lysine, histidine, valine, Cysteine, aspargine and tryptophane) (1%) and ascorbic acid (0.3 %).This nano fertilizer was purchased from Nano-research Biozar Company. Sprayed trees were of almost equal size (uniform) from one row and nano ZFM chlate in concentration of 2 g/l (2000 ppm) sprayed on shoots.

In order to detect the fruit set percentage, four branches with almost equal buds in different geographical sides of each tree were selected and marked. At first, all flower buds on each of the selected branches were counted. Then, the percentage of initial fruit set, final fruit set and harvest fruit set were measured with counting fruits in 15, 42, 126 days after full bloom respectively (Talahi *et al*., 2001 and Baybordi and Tabatabahi (2009): The fruit abscission percentage was estimated subtracting the initial fruit set from harvest fruit set percentage.

Concentration of Cu, Fe, Mn and Zn in almond leaves was measured by the Inductively Coupled Plasma system (Jons *et al*., 1991). Then after harvest, fresh weight of fruits (with green hull before drying and dry weight of nuts (without green hull after drying in sun for three days), fruit size (length and width and thickness) and yield were calculated on each marked branches. Yield factor was mentioned in the results as dry weight of nuts per each branch.

Finally, collected data were analyzed using SAS software, for comparison of means Duncan test at 5% level was used and the diagrams were drawn with EXCEL software.

Results

Analysis of variances showed that the interaction between cultivar and stage of fertilizer spraying was significant at 1% level for initial and final fruit set, fresh and dry weight of nut and yield of branch, and at 5% level for fruit width and length. However, in the case of fruit abscission only simple effects of cultivar or time of foliar spraying were significant (Table 4).

Table 4. Analysis of variance (ANOVA) of the effect of foliar treatment of nano-chelate super plus ZFM on quantity and quality traits in almond cultivars

S.O.V.	df	Mean of squares (MS)											
		Fruit abscission (%)	Initial Fruit set (%)	Final fruit set (%)	Fruit fresh weight (gr)	Fruit dry weight (gr)	Fruit width (cm)	Fruit length (cm)	Yield per branch	Zn of leaves (ppm)	Fe of leaves (ppm)	Cu of leaves (ppm)	Mn of leaves (ppm)
Replication	2	540.26**	56.4**	60.66**	5.33**	0.011 ns	0.043*	0.023*	3.9 ns	5.67**	1.5ns	0.18ns	2.1**
Cultivar (a)	2	926.37**	107.37**	207.81**	8.32**	0.908**	0.769**	0.543**	8822.6**	0.795**	46**	5.57**	36**
Time of application (b)	3	256.14**	51.14**	110.70**	3.25**	0.376**	0.284**	0.123**	7555.09**	23.783**	65.78**	95.4**	50.4**
a×b	6	26.48 ns	6.92**	0.981 **	0.68**	0.078**	0.052*	0.041*	231.12**	6.135**	191**	3.2*	150**
Error	22	15.29	0.62	0.903	0.107	0.012	0.011	0.013	13.65	4.941	43	1.15	30.1
Coefficient of variation		5.959	5.01	10.88	4.44	4.41	5.51	6.11	4.9	7.1	9.1	19.4	9.9

*, ** represents effects significant at probability levels of 0.05 and 0.01 respectively; ns means non-significant (P<0.05).

Interaction effect of the time of ZFM super plus fertilizer application and cultivars on microelements content in almond leaves

The interaction between cultivars and the stage of fertilizer spraying on concentration of microelements in almond leaves showed that in all of the cultivars, the control with no fertilizer had the lowest content of micro elements but with ZFM super plus fertilizer application especially at two stages, microelements content in leaves remarkably increased. Also the highest concentration of all microelements is observed in Shokufe cultivar in two stages of application (Table 5).

Table 5. Interaction of stage of fertilizer application and cultivar on concentration of microelements in almond leaves. T1: bud swelling phase, T2: two weeks after bloom end

	Shokufeh				Monaghah				Sahand			
Treatments / Microelements(ppm)	Control	T1	T2	T1 & T2	Control	T1	T2	T1 & T2	Control	T1	T2	T1 & T2
Zn	10 d	11.5 c	12.5 bc	16 a	10.5 d	12.5 bc	12.8 bc	14.9 b	11 cd	11.5 c	11.8 c	15 b
Fe	75 de	90.1 cd	100.3 c	120 a	80 d	99.2 c	105 b	110.4 b	80.2 d	90.8 cd	100 c	115.4 ab
Mn	20.3 e	50.2 c	59.5 bc	80.4 a	25 de	50.1 c	56.4 bc	73.7 b	28 d	45.4 c	50 c	70.9 b
Cu	4 e	7.8 c	8.2 b	10 a	4.4 e	7.2 c	8.3 b	9 ab	4.5 e	6.5 d	7c	8.54 b

Columns with common letters are not significantly different according to Duncan's test.

Effect of cultivars on fruit abscission of almond

The comparison of means showed that Sahand cultivar had the lowest percentage of fruit drop and Shokufeh and Monagha cultivars had no significant difference in terms of fruit abscission. The results showed that the percentage of fruit abscission in Shokufeh, Monagha and Sahand cultivars was 20%, 19% and 16% respectively (Fig. 1).

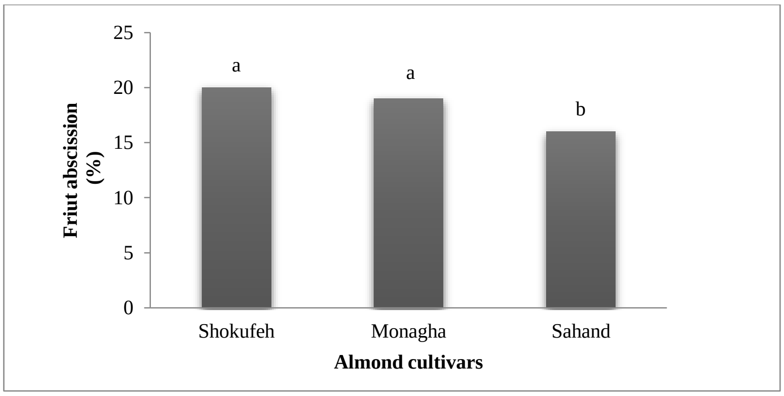

Fig.1. Effect of cultivar on fruit abscission percentage. .
Columns with common letters are not significantly different according to Duncan's test.

Effect of the time of ZFM super plus fertilizer application on fruit abscission of almond

The comparison of means of the effect of fertilizer spraying on fruit abscission percentage showed that the highest percentage of fruit abscission with average of 80.5% was observed in control with no fertilizer and the lowest percentage of fruit abscission with average of 21.5% was observed in fertilizer spraying at two stages namely bud swelling phase and two weeks after bloom end. The percentage of fruit abscission in spraying at bud swelling phase or two weeks after bloom end had no significant difference and the fruit abscission percentage of these treatments was 18% and 19.1%, respectively (Fig. 2).

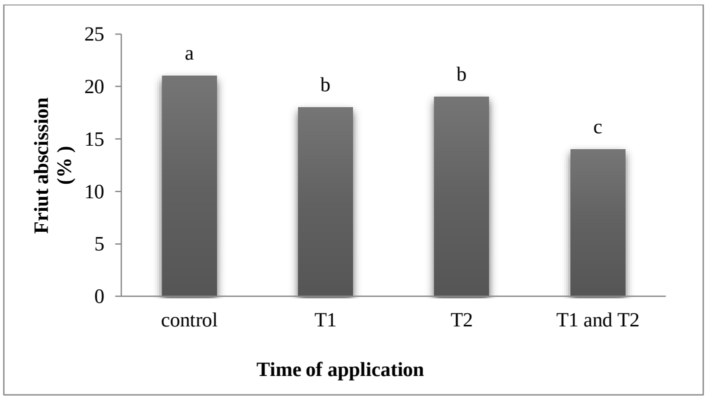

Fig.2. Effect of the time of ZFM application on fruit abscission percentage. T1: bud swelling phase, T2: two weeks after bloom end. Columns with common letters are not significantly different according to Duncan's test.

Interaction effect of the time of ZFM super plus fertilizer application and cultivars on initial and final fruit set percentage of almond

The interaction between cultivars and the stage of fertilizer spraying on initial and final fruit set showed that in Monagha and Shokufeh cultivars, the control with no fertilizer had the lowest percentage of initial and final fruit set, but in Sahand cultivar there was no significant difference between control and spraying before bud swelling phase or two weeks after bloom end. Fertilizer application at two stages in all tested cultivars showed the highest percentage of initial and final fruit set. The highest percentage of initial and final fruit set was 49% and 23%, respectively, in Shokufeh cultivar and fertilizer spraying at two stages (Figs. 3 and 4).

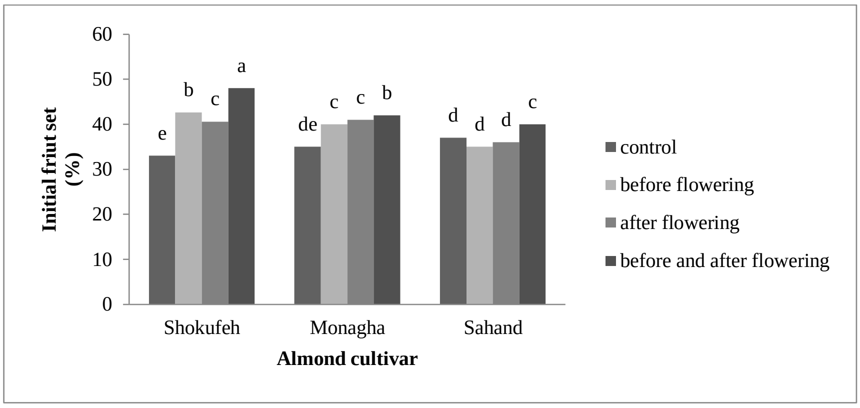

Fig. 3. Interaction of stage of fertilizer application and cultivar on initial fruit set percentage
Columns with common letters are not significantly different according to Duncan's test.

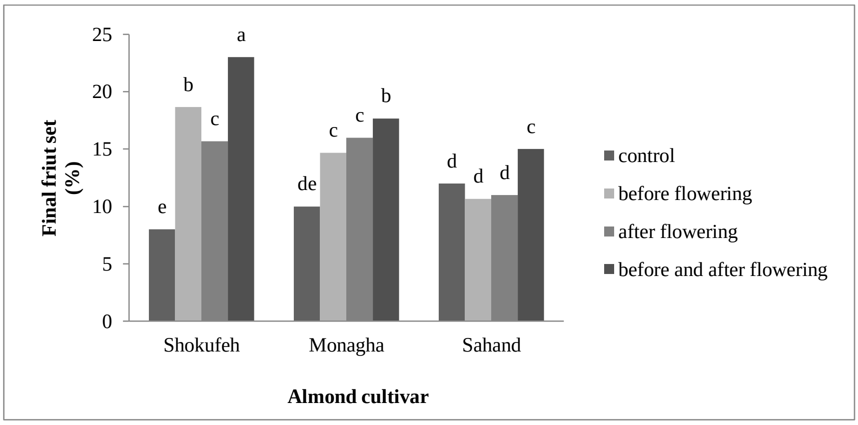

Fig. 4.Interaction of stage of fertilizer application and cultivar on final fruit set percentage
Columns with common letters are not significantly different according to Duncan's test.

Interaction effect of the time of ZFM super plus fertilizer application and cultivars on fresh weight of fruits in almond

The interaction between cultivar and stage of fertilizer spraying on fresh weight of fruit showed that it was different in different cultivars. The highest fresh weight of fruit was observed in Sahand cultivar and fertilizer spraying at two stages and it was about 9.2 g. The lowest fresh weight of fruit was observed in Sahand cultivar and the control with no fertilizer and it was about 5.8 g (Fig. 5).

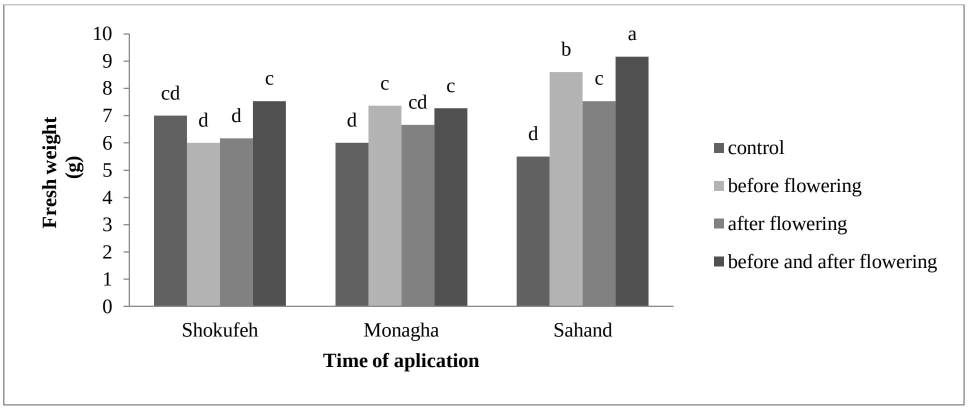

Fig. 5. Interaction of the stage of fertilizer application and cultivar on fresh weight of fruit
Columns with common letters are not significantly different according to Duncan's test.

Interaction effect of the time of ZFM super plus fertilizer application and cultivar on dry weight of fruits in almond

The interaction between cultivar and the stage of fertilizer spraying on dry weight of fruit showed that it was different in different cultivars. The highest dry weight of fruit was observed in Sahand cultivar and fertilizer spraying at two stages and it was about 3.2 g. The lowest dry weight of fruit was observed in control with no fertilizer and it was about 2 g (Fig. 6).

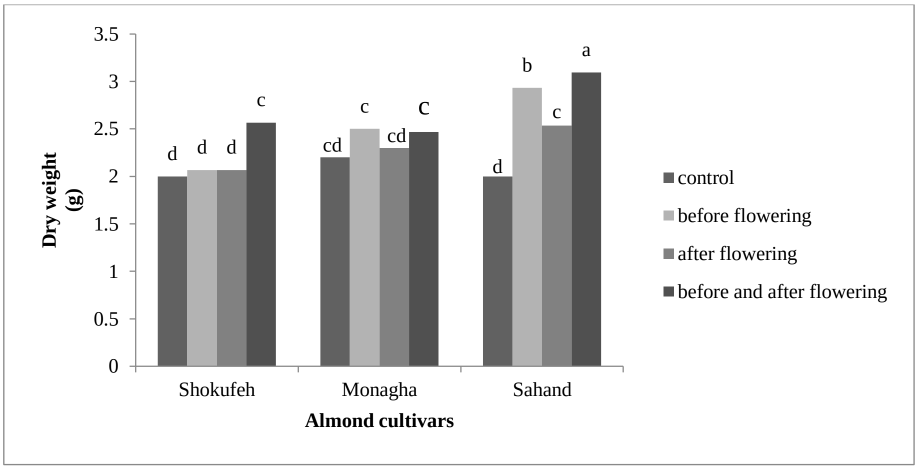

Fig. 6. Interaction of the stage of fertilizer application and cultivar on dry weight of fruit.
Columns with common letters are not significantly different according to Duncan's test.

Effect of interaction the time of ZFM super plus fertilizer application and cultivars on length and width of fruit in almond

The interaction between cultivar and the stage of fertilizer spraying on length and width of fruit showed that in all tested cultivars the fertilizer application at two stages caused the highest fruit width and length and control showed the lowest. The highest fruit width and length were observed in Sahand cultivar and fertilizer spraying at two stages and they were about 2.6 cm and 3.8 cm respectively. The lowest fruit width and length were observed in control and they were about 1.5 cm and 2.5 cm respectively (Figs. 7 and 8).

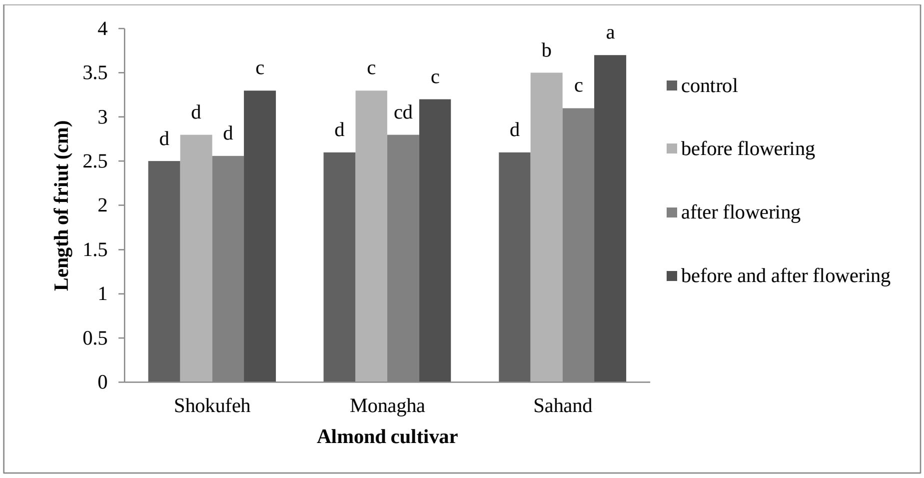

Fig. 7. Interaction of the stage of fertilizer application and cultivar on fruit length.
Columns with common letters are not significantly different according to Duncan’s test.

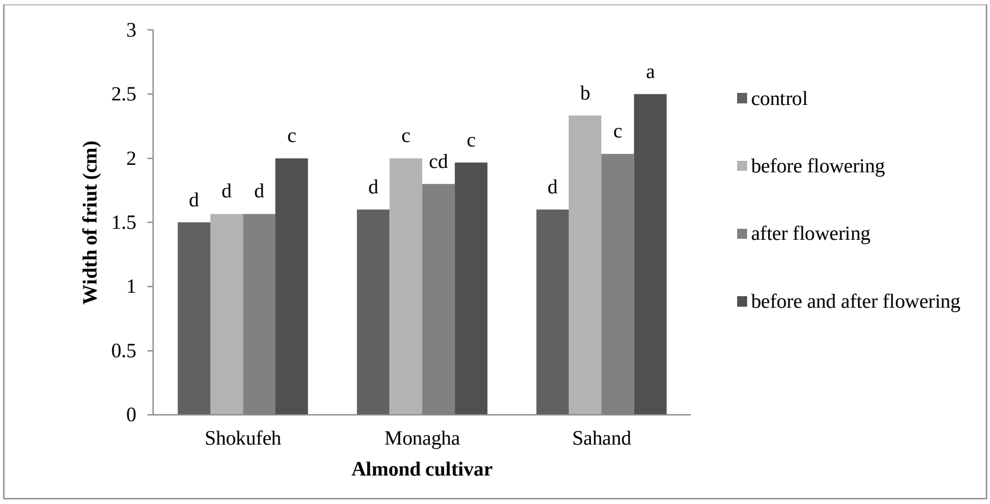

Fig. 8. Interaction of the stage of fertilizer application and cultivar on fruit width.
Columns with common letters are not significantly different according to Duncan’s test.

Interaction effect of the time of ZFM super plus fertilizer application and cultivars on Yield per shoot in different almond cultivars

The interaction between cultivar and the stage of fertilizer spraying on the yield of branch showed that the highest yield of branch was observed in Shokufeh cultivar and fertilizer spraying at two stages and it was about 350 g. The lowest yield of branch was observed in control of all cultivars and it was about 120 g (Fig. 9).

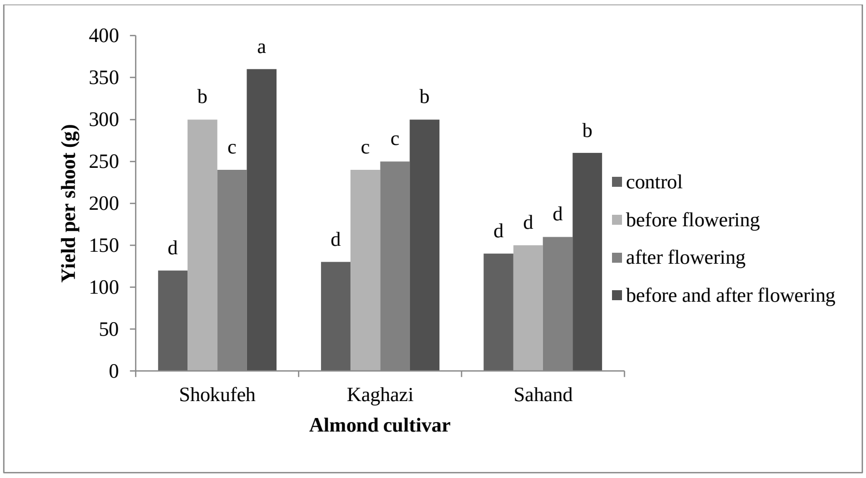

Fig. 9. Interaction of the stage of fertilizer application and cultivar on yield per shoot.
Columns with common letters are not significantly different according to Duncan's test.

Discussion

Leaf area is an important factor in the absorption of treated material from the nutrient solution that is sprayed. The nutrients absorb from cuticle or stomata on the leaf surface. When the stomata are closed, nutrient solutions are absorbed through water pores and the cuticle. Hence, the stomata are important and they can absorb aqueous solutions (Bybordi and Malakuti, 2005). If microelements are used as fertilizer in the soil, they will bond with soil particles and will not be absorbed easily by plant roots. Despite of the sufficient concentration of these elements in the soil, absorption by plant roots decreases and it will cause reduction of root growth and reduction of the product and its quality. Thus, foliar spraying is an efficient way for nutrition. In this research, fertilizer spraying of Nano-chelate Super Plus ZFM on almond trees played an important role in improving the yield and increasing the generative growth and fruit production. This test showed that this fertilizer is absorbed by leaves sufficiently and the concentration of tested microelements increased in leaves compared to control. Application of this nano fertilizer reduces fruit abscission and increases fruit set. Due to low concentration of nutrients especially Fe, Cu and Mn in soil and the important role of them in plant nutrition, this result was expected. The research on fruit trees have shown that the nitrogen, boron and zinc have the greatest effect on fruit set. These elements are necessary for some plant phenological stages such as fruit set stage (Morshedi, 2001).

At the beginning of growing season, low temperatures of environment, reduce nutrient uptake by root. On the other hand, stored nutrients from the previous year for the process of flowering and fertility are not enough (Swietlike and Faust, 1984). In this study, spraying zinc, iron and manganese, as well as amino acids compensated this deficit and flowering and fruit set increased. It can be due to an increase in vegetative growth and leaf area caused by microelements absorption especially zinc, iron and manganese as well as amino acids present in this fertilizer, which leads to an increase in photosynthesis and more production of assimilates that reduced fruit abscission. It corresponds with the results of Beed (1991) who showed that zinc sulfate spraying in late dormant stage of pistachio trees improves the zinc content of leaves. Amino acids increase nitrogen macro element in leaves of plants and help them to grow. Nitrogen has a structural role in chlorophyll, and nitrogen deficiency in plants such as almonds causes chlorophyll destruction, reduction of growth and chlorosis of leaves (Jonesa *et al.*, 2005). In terms of the fruit set increase by fertilizer spraying, it can be stated that during flowering, nitrogen of leaves is transferred to growing inflorescences and the competition between different consumer's changes (leaves, flowers and inflorescences) that leads to an increase in fruit set (Cimato and Fiorino, 1989, Cimato *et al.*, 1994).

Despite of sufficient amount of zinc in soil, the concentration of it in leaves was low, showing that high pH of soil inhibited the absorption of zinc by root which is one of the most important micro elements and is necessary for formation of fruits with desired size. Zinc is involved in enzymatic activity, synthesis of nucleic acids and proteins and all these factors have a significant impact on growth of flowers and on fruit set. It is also involved in carbonic anhydrase enzyme which is needed for chlorophyll biosynthesis in all photosynthetic tissues. It also plays a role in the synthesis of tryptophan which is a precursor of auxin synthesis (Castro and Sotomayor, 1997).

Manganese is needed for the activity of some enzymes involved in photosynthesis and protein synthesis (Fernandes *et al*, 1999). Iron also influences on the production of chlorophyll and carbohydrates in plant. Thus in iron and manganese deficiency, yield and fruit size are severely reduced (Jonesa *et al*, 2005). On the other hand, the use of amino acids in combined with three microelement (zinc, iron and manganese) can cause decreased stomatal resistance and increased stomatal conductivity that supplies sufficient carbon dioxide for photosynthesis. The results of this experiment showed that the use of this type of fertilizer significantly increased the weight of almond fruits, and this increase is associated with a positive effect of nutritional elements absorbed by leaves on growth and yield. The process involves the increased production of assimilates in the leaves and increased transport and storage of them in fruits.

Zinc deficiency in peach trees causes the production of small and deformed fruits with low quality. It has been shown that the application of zinc on mango trees increases the fruit weight and seed weight (Bahadur *et al*., 1998). Fertilizer spraying of orange trees with zinc in April and May increases fruit size, soluble solids content and water content of fruits (Dixi and Gamdagin, 1978).

Meyer *et al* (1997) reported that foliar feeding of almond trees cultivar butte with different amounts of nitrogen, phosphorus and potassium in the swelling stage of flower buds did not cause any significant increase in yield. But there are many studies about the effects of foliar application of nutrients, especially micro nutrients in enhancing the quality of flowering and fruit set percentage of fruit trees (Taheri *et al*., 2000, Baratta *et al*., 1992, Cimato and Fiorino, 1989, shrests *et al* 1987). In another research, Agnes *et al* (1997) reported that foliar application of boron on almond trees in early autumn increased the fruit set.

There is vitamin C in these fertilizers, which is an antioxidant factor and it can decrease the effects of environmental stresses, resulting in increased fruit set and decreased fruit abscission. There are similar results about the use of vitamin C in controlling the environmental stresses in pistachio (Molamohamadi *et al.*, 1393, Bastam *et al*., 2013, Kamiab *et al*., 2015). In this study, a significant increase was observed in the yield per branch, especially in fertilizer application in two stages. It is reported that nitrogen supply can increase ovule acceptance period (Zakinthions and Rouskas, 1995). Amino acids present in this fertilizer can be a good source of nitrogen. Meyer *et al*. (1997) also reported that foliar application of nutrients in spring in swelled bud stage significantly increased the yield.

Conclusions

Given that the amount of microelements in most of the almond orchards in Kerman province is at a level lower than intermediate level and because the yield and quality of this crop has fallen sharply in the recent years, this study was performed. The results of this study showed that there is a relationship between consumption of these elements and increase in fruit set. Thus, Nano-chelate super plus ZFM is a good method to remove nutrient deficiencies to increase quantity and quality of almond yield in the near future. Also the results showed that the application of this fertilizer at two stages is much more effective than its application at one stage.

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